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Growth of *R. harrisii* was significantly better in larvae fed Brazilian or Italian *Artemia* than in larvae fed the Australian strain. For *C. irroratus*, growth rate was equivalent in larvae fed Brazilian, Italian or Australian *Artemia*.

In a preliminary study, Utah and Brazilian *Artemia* strains were tested for temporal variability in their nutritional quality. Little short-term temporal variation was found in these two strains. This may result more from an artifact in time of collection than from actual temporal stability.

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International Study on *Artemia*[1] VI. Nutritional value of geographical and temporal strains of *Artemia* : effects on survival and growth of two species of Brachyuran larvae

D. Michael Johns, Mark E. Peters, and Allan D. Beck

United States Environmental Protection Agency, Environmental Research Laboratory
South Ferry Road, Narragansett, Rhode Island 02882, USA

Abstract

Five geographical strains of *Artemia* were compared for their effects on the survival and growth of *Rhithropanopeus harrisii* and *Cancer irroratus* larvae. High survival during larval development was provided by *Artemia* strains from Macau-Brazil, Margherita di Savoia-Italy and Shark Bay-Australia. The San Pablo Bay, California-USA, and Great Salt Lake, Utah-USA strains did not support survival beyond megalopa despite good survival in earlier development stages. During early development, larvae feeding on San Pablo or Utah strains exhibited either slower development rates (*C. irroratus* larvae) or a supernumerary zoeal stage (*R. harrisii*).

Growth of *P. harrisii* was significantly better in larvae fed Brazilian or Italian *Artemia* than in larvae fed the Australian strain. For *C. irroratus*, growth rate was equivalent in larvae fed Brazilian, Italian or Australian *Artemia*.

In a preliminary study, Utah and Brazilian *Artemia* strains were tested for temporal variability in their nutritional quality. Little short-term temporal variation was found in these two strains. This may result more from an artifact in time of collection than from actual temporal stability.

Introduction

A review of literature dealing with nutritional sources for the laboratory rearing of crustacean larvae reveals that *Artemia* nauplii are by far the most frequently used food source. Commercially available *Artemia* cysts are convenient to use and often support complete larval development. Historically, little attention has been paid to the geographical origin of the *Artemia* cysts used in crustacean culture. As a result, *Artemia* cysts from several regions, considered *a priori* to be equal in terms of supporting larval growth, have been widely used. In the past decade, however, research has indicated that cysts may vary geographically.

[1] International Interdisciplinary Study on *Artemia* Strains coordinated by the Artemia Reference Center, State University of Ghent, Belgium.

Forster and Wickins (1967) and Wickins (1972) report that larvae of *Palaemon serratus* fed *Artemia* nauplii hatched from cysts collected in Utah-USA die during development. Subsequent research has substantiated this claim (Little, 1969, rearing *Palaemon macrodactylus* larvae ; Reed, 1969, rearing *Cancer magister* larvae ; Reeve, 1969, rearing *Palaemon serratus* larvae ; Bookhout and Costlow, 1970, rearing five brachyuran species).

Several theories have been advanced to explain this apparent lack of nutritional quality in Utah *Artemia*. Bookhout and Costlow (1970) have presented evidence of pesticide contamination, while several other investigators (Shelbourne in Provasoli, 1969 ; Oppenheimer in Provasoli, 1969) have suggested biochemical deficiencies.

Other geographical strains of *Artemia* tested have generally proven to be adequate for promoting crustacean larval growth. The most commonly used source is from the San Francisco Bay-USA region, while other sources (several Canadian strains, Kurata, 1967 ; Dexter, 1972 ; Provenzano and Goy, 1976 ; and a San Fernando-Spain strain, Rodriguez, 1975) have also been used with some success.

The purpose of this research is to evaluate the nutritional quality of five geographical strains of *Artemia* for promoting development and growth of the larvae of two brachyuran crabs. In addition, preliminary research was begun to evaluate temporal variation in the nutritional quality of two of the geographical strains.

Materials and methods

Handling of the food source

Geographical strains of *Artemia* to be tested for their nutritional quality were collected from the following areas : 1) Brazilian strain – from Macau, Brazil ; 2) Italian strain – from Margherita di Savoia, Italy ; 3) Australian strain – from Shark Bay, Australia ; 4) San Francisco Bay strain – from San Francisco Bay Brand, California, USA[2] ; 5) Utah strain – from Great Salt Lake Region, Utah, USA. Further details about their origin and lot number can be found in Table I. The criteria used by the ISA-program in selecting the *Artemia* strains used in this study are reported in Sorgeloos (1980). To obtain stage one nauplii, cysts were incubated at 25 °C in 30 ‰ filtered (0.45 μm) seawater for a specified period of time which was dependent on the particular geographical strain (Table I). Hatched nauplii were harvested at the end of this time period, carefully separated from hatching debris, and fed to the crab larvae daily.

In addition to the five geographical strains tested, two other lots of both the Utah strain and the Brazilian strain were used to determine temporal variation in the nutritional quality of *Artemia*. Temporal samples assayed were collected on the following dates : Utah 1-1978 ; Utah 2-1977 ; Utah 3 – mixed years prior to 1977 ; Brazil 1-1978a ; Brazil 2-1978b ; Brazil 3-1979. Handling of these cysts and newly hatched nauplii was identical to that used for the geographical strains.

[2] Upon completion of this study we were informed that this batch is not from San Francisco Bay salt pans but from salinas in San Pablo Bay, located north of San Francisco (P. Sorgeloos, personal communication).

TABLE I

Summary of information on the five geographical strains of *Artemia* used in this study

Artemia strain	Collection site	Incubation conditions	Incubation time (hr)
Brazilian	Macau-Brazil, harvested 1978	25 °C-30 ‰	24
Italian	Margherita di Savoia-Italy, harvested 1977	25 °C-30 ‰	29
Australian	Shark Bay-Australia, World Ocean Brand, lot 113	25 °C-30 ‰	29
San Pablo Bay	San Pablo Bay region, California-USA, Living World, lot 1628[a]	25 °C-30 ‰	24
Utah	Great Salt Lake region, Utah-USA, harvested 1977	25 °C-30 ‰	23

[a] Labeled as San Francisco Bay *Artemia* cysts, Living World, San Francisco Bay Brand, Inc. Apparently collected from San Pablo Bay instead of San Francisco Bay (P. Sorgeloos, personal communication).

HANDLING OF THE CRAB LARVAE

Gravid *R. harrisii* were collected from under rocks in Pettaquamscutt River, Narragansett, Rhode Island-USA during the summers of 1978 and 1979. Gravid *C. irroratus* were collected by otter trawl from the west passage of Narragansett Bay, Rhode Island-USA between March and May, 1979. Females were isolated into either 20 cm finger bowls containing 25 °C, 25 ‰ filtered (0.45 μm) seawater (*R. harrisii*) or into 3 l plastic tubs containing 18-20 °C, 30 ‰ filtered seawater (*C. irroratus*). Newly hatched stage I zoeae (less than 18 hr post-hatching) were subsequently placed into 8 cm finger bowls with 10 zoeae per bowl. There were five bowls per diet for *R. harrisii* and three bowls per diet for *C. irroratus* for each experimental run. Larvae molting into megalopae were individually isolated into 2 cm finger bowls to prevent cannibalism. Experiments using *R. harrisii* were replicated six times (total of 300 larvae per diet) while those experiments using *C. irroratus* were repeated once (total of 60 larvae per diet).

Rearing conditions for the larvae were either 25 °C, 25 ‰ (*R. harrisii*) or 20 °C, 30 ‰ (*C. irroratus*). Daily, larvae were transferred to fresh seawater, examined for mortality, and then were fed an excess of newly hatched nauplii (750-1500 per bowl or 200-300 per megalopa) from the appropriate *Artemia* source. Surviving larvae were reared to the first crab stage (*R. harrisii*) or to the megalopa stage (*C. irroratus*). Then, a portion of the crabs were frozen for biochemical analysis ; and the remaining crabs were rinsed in deionized water, dried to a constant weight at 60 °C and weighed to the nearest 1.0 μg on a Perkin Elmer auto balance[3].

Because early results suggested that high mortality may occur during the stage IV – megalopa molt in larvae fed certain diets, a separate experiment was designed. *R. harrisii* crab larvae were reared on the various *Artemia* strains to late stage IV larvae, and then were sacrified for both biochemical analysis and dry weight determinations.

[3] Reference to trade names does not imply endorsement by the United States Environmental Protection Agency.

Experiments using the temporal collections of *Artemia* as food sources were handled in the same manner as previous experiments. However, only *R. harrisii* larvae were used in these experiments, which were repeated three times (total of 150 larvae per food source).

Data analysis

One-way analysis of variance was computed on an every-other-day basis for larval survival rates. In order to normalize survival data, survival rates were transformed to angles (arcsine $\sqrt{}$ percent) prior to analysis (Snedecor and Cochran, 1967). One-way analysis of variance was also computed for the dry weights of animals at stage IV, megalopa, and first crab stage. If significant differences (at $P \leq 0.05$) were found between crab larvae fed the various food sources, a Student-Neuman-Keuls posterior comparison was used to determine where the differences lay.

Results

Geographical strains – *Rhithropanopeus harrisii*

Food source had a significant effect on the survival of *R. harrisii* larvae (Fig. 1, Table II). Differences between the treatments were not significant until day 10. Thereafter, mortality of crab larvae fed either San Pablo Bay (SPB) or Utah brine shrimp nauplii increased sharply. Larvae fed the other geographical strains continued to survive well after day 10 with little increase in mortality (Fig. 1).

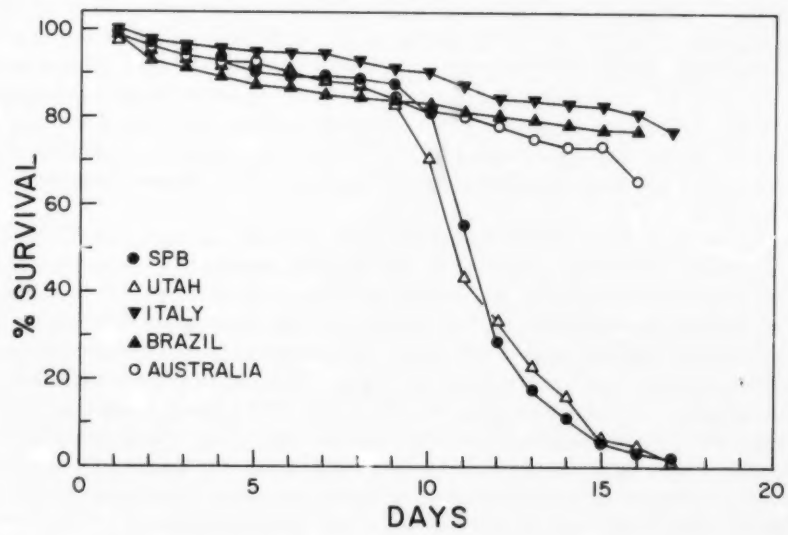

Fig. 1. Survival of *Rhithropanopeus harrisii* larvae fed various geographical strains of *Artemia* during larval development.

TABLE II

Analysis of variance of survival for *Rhithropanopeus harrisii* larvae fed various geographical strains of *Artemia* nauplii. * indicates significant differences in survival of the larvae fed the various food sources ($P \leq 0.05$). SNK = Student-Neuman-Keuls posterior test. *Artemia* strains grouped on the same line are not significantly different from each other while those on different lines are significantly different

Time post-hatch (days)	F-ratio	SNK
2	1.19	
4	1.18	
6	0.81	
8	1.30	
10	4.20*	Utah SPB. Brazil. Australia. Italy
12	34.70*	Utah. SPB Brazil. Australia. Italy
14	63.35*	Utah. SPB Brazil. Australia. Italy
16	116.85*	Utah. SPB Brazil. Australia. Italy
18	66.77*	Utah. SPB Brazil. Australia. Italy

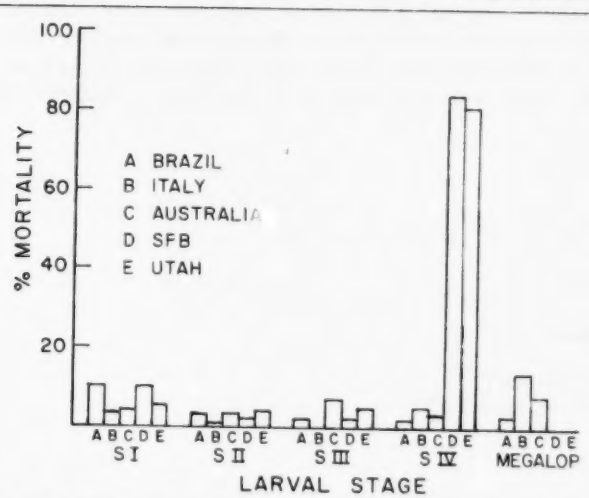

FIG. 2. Stage by stage breakdown of mortality for *Rhithropanopeus harrisii* larvae fed various geographical strains of *Artemia*.

A stage-by-stage breakdown of mortality indicates that patterns of larval mortality differed little in the zoeal stages I, II and III (Fig. 2, Table III). At zoeal stage IV, however, mortality rose sharply for larvae fed SPB and Utah strain *Artemia*. Mortalities during this stage primarily occurred during the stage IV – megalopa molting period rather than during the stage IV intermolt period.

TABLE III

Summary of rearing data for *Rhithropanopeus harrisii* fed various geographical strains of *Artemia*. ND = no data collected; 100% mortality prior to this stage. Data are presented as a means ± one standard deviation

Parameter	Brazilian	Italian	Australian	San Pablo Bay	Utah
% survival to 1st crab	77 ± 13	85 ± 10	61 ± 26	0	0
% survival to megalopa	80 ± 12	92 ± 7	78 ± 25	0	0
% survival of megalopa to 1st crab	96 ± 5	85 ± 9	76 ± 14	ND	ND
Time from hatch to SIV – megalopa molt (days)	11.1 ± 1.3	10.3 ± 0.2	11.1 ± 1.2	11.0 ± 1.1	10.8 ± 0.8
Time from hatch to 1st crab	16.7 ± 1.2	15.6 ± 0.2	16.4 ± 1.1	ND	ND

A number of molting irregularities appeared during the zoeal stage IV – megalopa molting period in those larvae fed either San Pablo Bay or Utah strain nauplii (Table IV). The most common irregularity was the presence of a dorsal spine on larvae after the zoeal stage IV molt. Apparently, the larval stage resulting from this molt was not an abnormal megalopa but rather represents a supernumerary stage. In support of this hypothesis, two larvae fed the Utah strain successfully molted from normal stage IV larvae into larvae possessing the dorsal spine irregularity. These larvae then successfully molted into recognizable megalopae before dying.

TABLE IV

Summary of molting irregularities found in *Rhithropanopeus harrisii* and *Cancer irroratus* larvae fed either the San Pablo Bay or Utah strains of *Artemia*

Molting irregularities	*R. harrisii* larvae	*C. irroratus* larvae
Died during molting process	+	+
Partial molting	+	+
Unusual carapace spination	+	–
Zoeal maxillipeds present after molt	+	–

Diet had no effect on development time to either the stage IV – megalopa molt or to the first crab stage for surviving larvae (Table III). Mean development times to the stage IV – megalopa molt and to the first crab stage were approximately 10.5 days and 16 days, respectively.

The effect of diet on larval growth was determined twice during development, both at late intermolt stage IV and again at the first crab stage (Table V). No significant differences between larvae fed the different geographical strains were found in growth to stage IV. For larvae surviving to the first crab stage, however, those fed the Brazilian and Italian strains of *Artemia* were significantly heavier than crabs fed the Australian strain.

TABLE V

Dry weight of stage IV zoea and the first crab stage of *Rhithropanopeus harrisii* fed various geographical strains of *Artemia*. ND = no data collected ; 100% mortality prior to this stage. Means with the same superscript are not significantly different ($P > 0.05$) while means with different superscripts are ($P < 0.05$)

Food source	Stage IV dry weight (μg)	1st crab dry weight (μg)
Brazilian	98 ± 11^a	292 ± 55^a
Italian	94 ± 13^a	285 ± 40^a
Australian	99 ± 12^a	246 ± 45^b
San Pablo Bay	92 ± 8^a	ND
Utah	86 ± 14^a	ND

GEOGRAPHICAL STRAINS – *CANCER IRRORATUS*

As with *R. harrisii*, food source had a significant effect on survival of *Cancer irroratus* larvae (Fig. 3, Table VI). Survival of larvae fed the Utah strain nauplii was similar to that of larvae in the other treatments until day 18, when pronounced mortality during the stage V – megalopa molt and the megalopa stage began to occur. Survival of larvae fed the SPB strain, on the other hand, was high until day 21, after which mortality increased. Larvae fed the other three strains exhibited good survival to the megalopa stage.

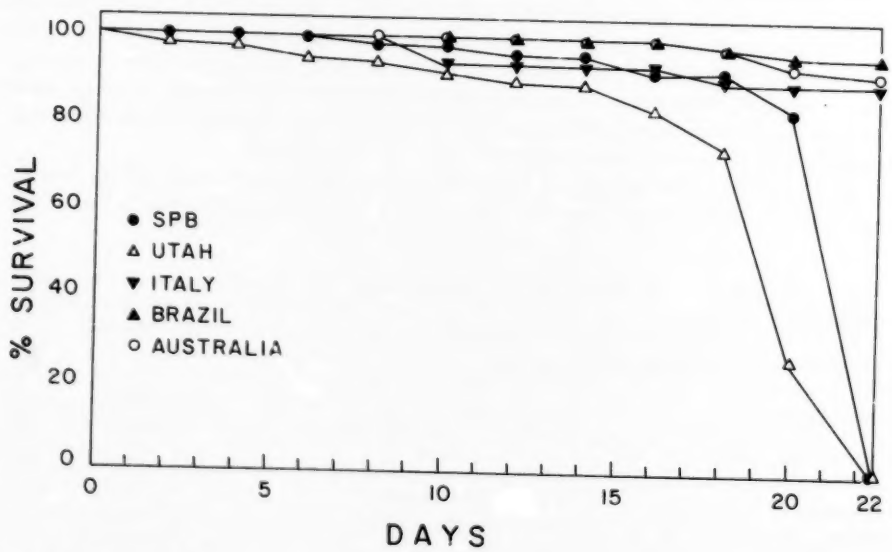

FIG. 3. Survival of *Cancer irroratus* larvae fed various geographical strains of *Artemia* during larval development.

TABLE VI

Analysis of variance of survival for *Cancer irroratus* larvae fed various geographical strains of *Artemia* nauplii. * indicates significant differences in survival of the larvae fed the various food sources ($P < 0.05$). SNK = Student-Neuman-Keuls posterior test. *Artemia* strains grouped on the same line are not significantly different from each other, while those on different lines are significantly different

Time post-hatch (days)	F-ratio	SNK
2	1.25	–
4	0.94	–
6	0.98	–
8	1.14	–
10	1.32	–
12	1.53	–
14	1.94	–
16	3.63*	Utah, SPB Brazil, Australia, Italy
18	2.91*	Utah, SPB Brazil, Australia, Italy
20	16.5 *	Utah, SPB Brazil, Australia, Italy
22	83.4 *	Utah, SPB Brazil, Australia, Italy

Larvae fed SPB and Utah strains exhibited certain molting irregularities similar to those seen in *R. harrisii* larvae (Table IV). No larvae fed either the SPB or Utah *Artemia* successfully molted into megalopae in the initial experiment. In the replicate experiment, however, larvae that were normally fed the Utah strain were fed the Brazilian strain on the 17th day due to a poor hatch in the Utah strain *Artemia*. Larvae from these bowls subsequently exhibited fewer molting irregularities than in the previous run, and some successfully molted into megalopae. Resulting megalopae died shortly after molting (< 36 hr), however.

Development time to the stage V – megalopa molt was significantly prolonged in larvae fed either SPB or Utah nauplii (Table VII). Mean molting times for larvae fed the SPB and Utah

TABLE VII

Development times and dry weights for the megalopa stage of *Cancer irroratus* reared on various geographical strains of *Artemia*. Means with the same superscript are not significantly different ($P > 0.05$) while means with different superscripts are ($P < 0.05$). ND = no data collected, 100% mortality prior to this stage. Data are presented as a means ± one standard deviation

Food source	Development time to megalopa from post-hatch (days)	Megalopa dry weight (μg)
Brazilian	18.28 ± 0.63^a	472.57 ± 74.18^a
Italian	18.18 ± 0.68^a	447.83 ± 64.20^a
Australian	18.20 ± 0.85^a	444.13 ± 59.83^a
San Pablo Bay	21.84 ± 1.13^c	ND
Utah	19.60 ± 1.01^b	346.14 ± 51.02^b

strains were 21.8 and 19.6 days, respectively ; contrasting with approximately 18 days for all other strains.

Growth to the megalopa stage was not significantly different for larvae fed the Brazilian, Italian or Australian strains (Table VII).

Temporal studies – *Rhithropanopeus harrisii*

Generally, little temporal variation in nutritional quality was found in the two geographical strains of *Artemia* tested. Utah collections supported equally poor growth and survival (Fig. 4), while the Brazilian collections promoted high survival rates (Fig. 5).

Some difference between the Utah temporal strains did appear at the stage IV – megalopa molt. More larvae fed either Utah-mixed or Utah 1977 successfully molted into the supernumerary stage than did larvae fed Utah 1978. One-hundred percent mortality occurred in this stage, however, just as in larvae fed Utah 1978. Furthermore, some minor reduction in survival was observed in larvae fed the Brazilian 1978b strain relative to the other two Macau-Brazil samples.

Discussion

Geographical strains – larval survival

Artemia is generally accepted as the most promising food source in rearing brachyuran larvae. Except for the early zoeal stages of some brachyurans which are too small to feed on brine shrimp, survival of *Artemia*-nourished larvae from hatching through metamorphosis is common (Bookhout and Costlow, 1974). Different geographical strains of *Artemia* have been used in rearing larvae with variable degrees of success (Bookhout and Costlow, 1970 ; Dexter, 1972 ; Wickins, 1972 ; Provenzano and Goy, 1976).

With the larvae of the two brachyurans used in this study, rearing success was dependent on the geographical strain used. The Utah and SPB strains did not support survival past the megalopa stage, whereas the Brazilian, Italian, and Australian strains promoted good survival and complete development to the first crab stage. Chlorinated hydrocarbon analysis of these five geographical strains suggests a possible chemical basis for observed differences in nutritional quality between *Artemia* strains. Although Olney *et al.* (1980) detected small amounts (4 to 433 ppb) of DDT in all five geographical types with highest contamination in the Italian strain, they measured significant amounts of dieldrin and chlordane only in the Utah and SPB strains.

The Utah strain has previously been shown to be of suspect quality in supporting survival and growth of crustacean larvae. Bookhout and Costlow (1970) report that the mud crab *Hexapanopeus angustifrons* did not survive well when fed Utah *Artemia* and that other crab larvae, although surviving as well as those fed San Francisco Bay *Artemia*, were abnormal in appearance. Wickins (1972), furthermore, found that newly hatched Utah *Artemia* would not support larval development of the prawn *Palaemon serratus* unless the brine shrimp were fed the green alga *Isochrysis galbana* prior to their use as food. Possible reasons for poor survival of larvae fed Utah *Artemia* remain unclear. Bookhout and Costlow (1970) report higher pesticide levels in the Utah strain than in the San Francisco Bay strain. In contrast, Wickins (1972), reports much lower pesticide levels with the differences between the Utah and San

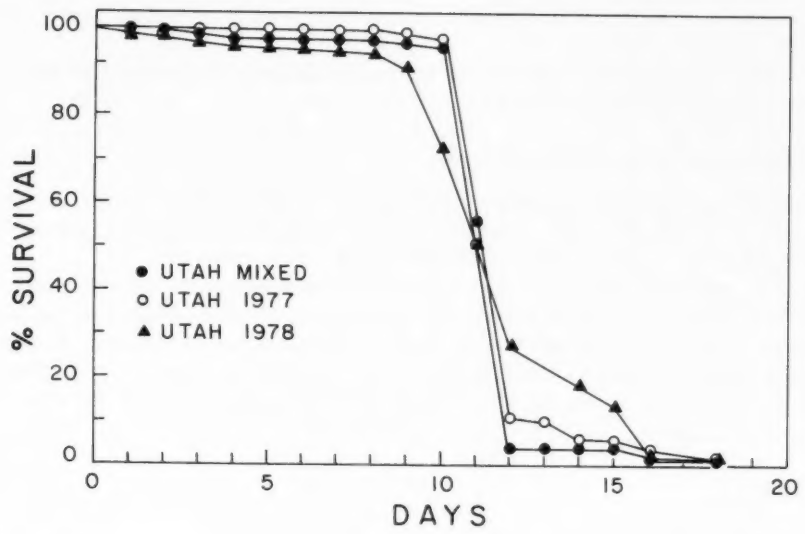

FIG. 4. Survival of *Rhithropanopeus harrisii* larvae fed temporal collections of *Artemia* collected from Great Salt lake, Utah-USA. Utah mixed = mixed years prior to 1977.

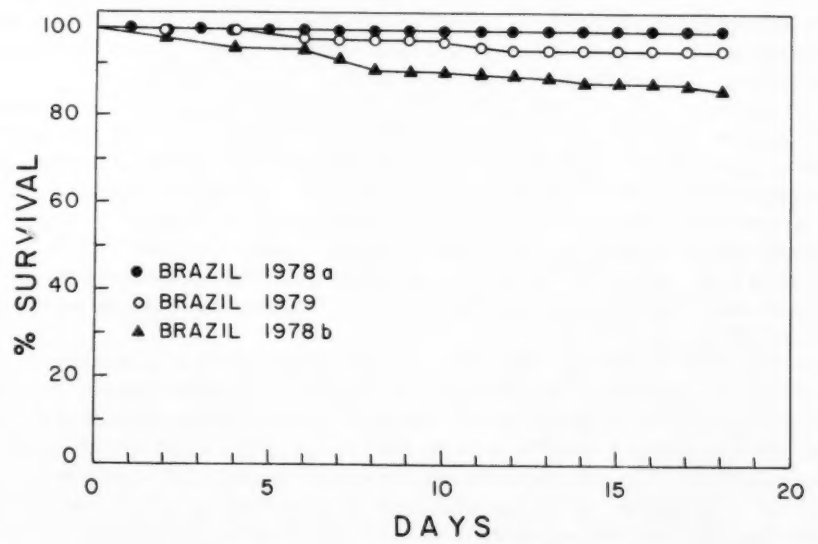

FIG. 5. Survival of *Rhithropanopeus harrisii* larvae fed temporal collections of *Artemia* collected from Macau-Brazil.

Francisco Bay strains very slight. Copper levels, on the other hand, were twice as high in the Utah strain as in San Francisco Bay *Artemia*. Other explanations, primarily dealing with differences in biochemical composition, have been suggested but have not been experimentally assessed (Provasoli, 1969).

Our relatively poor results with SPB nauplii are noteworthy since prior to this study, California-collected *Artemia* have often been used as the standard diet to which all other diets were compared (Sulkin and Epifanio, 1975 ; Sulkin and Norman, 1976). In addition to our data, poor survival of fish larvae fed SPB *Artemia* from the same lot used in this study has also been reported (Beck *et al.*, 1980 ; Klein-MacPhee *et al.*, 1980). A possible explanation for these results is provided by Olney *et al.* (1980) who found substantial levels of dieldrin (1.4 ppb) and chlordane (14 ppb), in nauplii hatched from the same lot of SPB cysts as that used in this study. Low concentrations of dieldrin (5 ppb) are known to be acutely toxic to larvae of the crabs *Leptodius floridanus* and *Panopeus herbstii* (Epifanio, 1971). High levels of pesticide contamination in SPB cysts would not be surprising, since San Pablo Bay is the receiving water for the extensively cultivated Napa Valley Region.

Although the observed correlation between survival results and pesticide levels is suggestive, it may not be causal. Other chemical characteristics of *Artemia* nauplii, such as heavy metal or fatty acid content, may be involved. Long chain polyunsaturated fatty acids are essential in the growth of marine fish (Watanabe *et al.*, 1978). Although the necessity of these fatty acids has yet to be shown for brachyuran larvae, they are present in the Brazilian, Italian and Australian strains and absent in the SPB and Utah strains (Schauer *et al.*, 1980).

Successful rearing of crustacean larvae on the other three strains of *Artemia* (Brazilian, Italian, and Australian) has not been previously reported. Survival values for larvae fed these strains are comparable to literature values for *R. harrisii* larvae (Costlow *et al.*, 1966 ; Bookhout and Costlow, 1970) and for *C. irroratus* larvae (Sastry, 1970 ; S. Vargo, personal communication) reared on San Francisco Bay *Artemia*.

Geographical strains – growth and development rate

Brachyuran larval development follows a set pattern in which there are a predictable number of zoeal stages followed by a megalopal stage before metamorphosis into a juvenile crab. Variation in the number of zoeal stages has been induced in laboratory cultures by varying rearing conditions (Ong and Costlow, 1970) or by adding pollutants to the rearing medium (Bookhout *et al.*, 1972). Under normal rearing conditions, *R. harrisii* larvae pass through four zoeal stages while development of *C. irroratus* involves five zoeal stages.

When fed either the Utah or SPB brine shrimp, some of the *R. harrisii* larvae in this study molted into a supernumerary zoeal stage rather than directly into the megalopal stage. Only twice did the supernumerary stage survive to molt into the megalopal stage, and these larvae died prior to completing larval development. Costlow (1968) postulated that there are at least two neuro-secretory mechanisms involved in controlling larval development. One mechanism controls molting rate while the other, usually synchronized with molting, controls the rate of morphological development within each larval stage. Pesticides, which commonly act as neuro-toxins, (O'Brien, 1967) may affect either one of these control mechanisms independently or both mechanisms together. For example, Epifanio (1971) found that dieldrin in concentrations of 1 ppb increased the duration of crab larval development by 11.4% without

altering the morphological changes apparent at each molt. Similarly, low concentrations of mirex (0.01 ppb) prolonged the larval development of *R. harrisii* larvae (Bookhout *et al.*, 1972). On the other hand, Bookhout *et al.* (1972), found that mirex did not alter larval development rates in *Menippe mercenaria* but rather caused an increase in the incidence of a supernumerary zoeal stage. It is not predictable, then, what effects a particular pesticide may have, except that alterations in neuro-secretory functions are often involved.

In contrast with most other investigations, pesticides in our study were introduced incidentally as part of the food source rather than directly into the rearing water. Hence, strict comparisons with literature values of pesticide concentrations cannot be made. However, prolonged larval development (*C. irroratus* larvae fed Utah or SPB nauplii) and the appearance of supernumerary stages (*R. harrisii* larvae fed Utah or SPB nauplii) did occur when food sources containing detectable amounts of dieldrin and chlordane were fed to the larvae. Again, a causal relationship is uncertain.

Interestingly, all five strains assayed contained DDT family compounds (up to 422 ppb), but no discernable changes in normal crab larval morphology or in the normal sequence and duration of development were manifest in larvae fed the Brazilian, Italian, and Australian strains. Furthermore, larval growth in terms of dry weight was similar for each decapod on all diets except for *R. harrissi* larvae fed the Australian strain. This contrasts with the findings of Bookhout and Costlow (1970) who reported deleterious effects in crab larvae fed Utah *Artemia* containing 7.05 ppb DDT. However, since DDT was the only pesticide assayed in their study, it may be that other contaminating pesticides were responsible for the observed differences.

Temporal studies – survival

The nutritional quality of an *Artemia* source might be expected to vary temporally as well as geographically. Short-term changes in the diets of adult *Artemia* or changes in the pollutant level of salinas where cysts are harvested could have an impact on the quality of resultant nauplii as a food source. Our preliminary results, however, indicate that there is relatively little short-term variation in the nutritional quality of brine shrimp nauplii from a specific region. Temporal samples of both the Utah strain (collected over a 2 to 3 year period) and the Brazilian strain (collected over a 2 year period) generally promoted similar growth and survival of crab larvae. An exception is the Brazilian 1978b strain which supported somewhat lower larval survival than the other Brazilian temporal strains. An explanation for this reduction in survival may be forthcoming when biochemical analysis is completed on these *Artemia* collections. Johns *et al.* (1978) apparently found significant temporal variation in the nutritional quality of San Francisco Bay *Artemia* when they compared survival and growth of mud crab larvae reared either on brine shrimp harvested prior to 1976 or on *Artemia* cysts harvested in 1978. Since the completion of that study, however, it has been determined that the 1978 collection was actually made from San Pablo Bay rather than from San Francisco Bay. Hence, the possibility of some degree of geographical variability cannot be excluded.

Sources of error

Potential sources of error associated with studies of this type include variability between hatches of crab larvae and seasonal factors involving the collection of the *Artemia* cysts.

Both inter-female and seasonal hatch variability are known to occur with decapod larvae (Sastry and Vargo, 1977). On several occasions we observed poor hatch survival from an egg mass that did not appear to be damaged or parasitized. Sastry and Vargo (1977), furthermore, found distinct seasonal variation in the temperature and salinity tolerance of *Cancer irroratus* larvae. Larvae from crabs collected in the spring tolerated a wider range of temperature and salinity than did larvae from crabs collected in the fall or summer (*loc. cit.*). Such physiological variation may also be reflected in larval survival and feeding response.

Details of collection and processing of commercially obtained *Artemia* cysts are unknown variables. Cyst production in the salinas normally occurs several times per year at intervals associated with episodes of maximum salinity and large diurnal fluctuations in the dissolved oxygen concentration (Sorgeloos *et al.*, 1977). Seasonal variation in the long chain poly-unsaturated fatty acid composition of *Artemia* cysts from a single location has been demonstrated (Watanabe *et al.*, 1978). Seasonal variability, then, may be as important as differences between years in determining the nutritional quality of an *Artemia* source.

Although we examined the nutritional value of cysts collected over a two year period, this time frame may be too short to reflect any major changes in the salinas caused by shifts in local agricultural or industrial activity. Hence, we have not systematically examined either short-term seasonal changes or long-term anthropogenic changes in our temporal analysis.

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